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REPORT OF THE THIRTY-FIRST ANNUAL MEETING OF THE OHIO ACADEMY OF SCIENCE

E. L. RICE
Secretary

The Thirty-first Annual Meeting of the Ohio Academy of Science was held at Western Reserve University and Case School of Applied Science, Cleveland, Ohio, March 25 and 26, 1921, under the Presidency of Mr. W. H. Alexander. Fifty-nine members were registered as in attendance; forty-seven new members were elected.

In accordance with the practice begun in 1918, but of which discontinuance has since been threatened, a geological excursion was organized by Professor J. E. Hyde, Vice-President for Geology, 1921–22, for the three days, May 28, 29 and 30. The party was under the guidance of Drs. August Foerste and W. H. Shideler. The itinerary (Wilmington, Clarksville, Fort Ancient, Oregonia, Dayton) was planned for the study of the Richmond formations of southwestern Ohio. Like other Academy functions, the excursion was open to non-members as well as members; fifteen geologists were present.

GENERAL PROGRAM.

FRIDAY, MARCH 25.

9:30 A. M.—Business Meeting.
11:00 A. M.—Reading of Papers in General Session.
12:30 P. M.—Luncheon.
2:00 P. M.—Demonstrations.
2:30 P. M.—Reading of Papers in General Session.
3:30 P. M.—Lecture by Dr. Henry H. Goddard, Bureau of Juvenile Research, Columbus, on "Scientific Work at the Bureau of Juvenile Research."
4:30 P. M.—Reading of Papers in General Session.
6:30 P. M.—Dinner.

8:00 P. M.—Address by the President of the Academy, Mr. W. H. Alexander, U. S. Weather Bureau, Columbus, on "Thunder Storms: Especially Those of Ohio."
9:00 P. M.—Adjourned Business Meeting.

SATURDAY, MARCH 26.

9:00 A. M.—Adjourned Business Meeting.
10:00 A. M.—Lecture by Professor Charles A. Kofoid, University of California, Berkeley, California, on "Hookworm and Human Efficiency."
11:00 A. M.—Reading of Papers in Sectional Meetings.
2:00 P. M.—Demonstrations.

SATURDAY, MAY 28—MONDAY, MAY 30.

Excursion by Section for Geology.

MINUTES OF BUSINESS MEETINGS.

The first business session was called to order by President Alexander at 9:30 A. M., on Friday, March 25. Adjourned sessions were held after the presidential address on Friday evening and at 9:00 A. M. on the following day.

The appointment of the following committees for the meeting was announced by the chair:

Committee on Membership—F. C. Waite, E. L. Fullmer, J. E. Hyde.

Committee on Resolutions—C. G. Shatzer, R. C. Osburn, W. H. Bucher.

Committee on Necrology—J. E. Hyde.

The following Auditing Committee was elected by the Academy: L. B. Walton, E. L. Fullmer.

The following Nominating Committee was elected by the ballot of the Academy: F. H. Herrick, E. L. Fullmer, J. E. Carman, F. C. Waite, H. H. Young.

Report of the Secretary.

The following report by the Secretary was received and ordered filed:

March 22, 1921.

To the Ohio Academy of Science:

Much of the work of the Secretary is covered by the Report of the Executive Committee.

The following brief note from Mr. McMillin, in reply to the Secretary's notification of election as patron and fellow, will be of interest to the membership of the Academy and may well have a permanent place in the records of the Academy:

DARLINGTON, MAHWAH, N. J., July 3, 1920.

DEAR MR. RICE:

Your good letter of July 1st was received a few moments ago. I thank the Society for all the honors they have conferred upon me, and greedily accept them all.

Most sincerely yours,

EMERSON MCMILLIN.

Edward L. Rice, Sec'y, Ohio Academy of Science.

There has been some additional correspondecne with the National Research Council concerning the research work of the Academy.

An appeal for the students of the Department of Geography of the Hungarian University of Debreczen was received under date of December 7, and will be presented later in the meeting.

A brief report of the Thirtieth Annual Meeting was prepared for *Science*, and appeared in the issue for August 6th.

In accordance with the instructions of the Academy, the Secretary prepared the Constitution, as amended to date, for reprinting, and it appeared in the Proceedings in connection with the Report of the Annual Meeting.

A number of technical changes in the form of the membership list were necessitated by the designation of fellows and national members (i. e., Academy members who are also members of the American Association for the Advancement of Science). In this revision errors may well have crept in; the secretary will be very grateful for corrections of such mistakes in order that the next list may be made as accurate as possible.

Respectfully submitted,

EDWARD L. RICE, *Secretary.*

Report of the Treasurer for the Year 1920-'21.

The report of the Treasurer was received as follows, and referred to the Auditing Committee, whose report is appended.

Balance in Hayden-Clinton Bank, May 13, 1920, as previously reported	$ 363.90
Deposits	1,357.90
Total	$1,721.80
Less checks	1,206.06
Balance in bank March 17, 1921	$515.74

The distribution of the funds expended is as follows:

To members of the Ohio Academy as refunds from the A. A. A. S.	$ 46.00
To E. L. Rice, Secretarial expenses	12.51
To Independent Print Shop	53.25
To Spahr & Glenn, Printers	8.75
To Hiss Stamp Company	1.40
To James S. Hine for Ohio Journal of Science	500.00
To T. C. Mendenhall, for coupons from bond	4.15
To B. E. Livingston for A. A. A. S.	580.00
	$1,206.06

Cr.

Balance carried forward	$ 363.90	
Cash deposited	1,357.90	
		$1,721.80

Dr.

As itemized expenditures	$1,206.06	
Balance in hand	515.74	
		$1,721.80

The Treasurer feels that the Academy is on a sound financial basis as is indicated in the report. He wishes to take this occasion to thank the members of the Ohio Academy of Science for their cordial support. There have been several cases of delays and misunderstandings in the collection of the joint dues for the American Association for the Advancement of Science and for the Academy. This is greatly to be regretted but from a careful study of the methods of payment, the Treasurer believes that the system will be practically automatic in another year. In order to avoid all trouble and inconvenience, prompt payments should be made in the early autumn when the bills are sent out. This insures prompt notification of the subscription managers of *Science* and of the OHIO JOURNAL OF SCIENCE and uninterrupted delivery of the two journals. Unless the Treasurer has the unanimous co-operation of the members in the matter of promptness, he cannot assure them of immediate attention. He is at all times glad to have reports of errors or delays and willing to do everything he can to adjust matters to the satisfaction and convenience of the members. During the year the present Treasurer has just served he has done practically all the work of billing, dunning, and corresponding unaided. This was done, not so much with the desire to save the slight cost of additional help, as in the hope that he might come to know all the details of the job and especially to straighten out accounts of members in arrears. It is to be hoped that members will take care of their arrearage sooner in the future, but this matter, in the case of those members of the Academy who are also A. A. A. S. members, will quickly adjust itself. In the itemized account of the funds the deposits are somewhat swelled because of arrearage. Because there is no adequate adjustment of this for the Ohio JOURNAL an increase to the JOURNAL was given this year.

While this increase for the JOURNAL comes at a time when it is greatly needed, it should be clear in the minds of the members that the Treasurer does not condone arrearages. A periodical journal can not subsist on alternate fat and lean years. It is desirable that its pabulum be more evenly distributed. Further the Treasurer is definitely preparing to meet the future expansion of the OHIO JOURNAL OF SCIENCE. He believes in it thoroughly and wishes to make it an adequate medium of expression for all the members. The JOURNAL ought to appeal especially to the younger members of the Academy. They need to publish articles in order to become introduced to the older scientific workers. The Treasurer feels that all the money that can be put into the JOURNAL is still not nearly enough to make it the best one of its kind in the country. By making it attractive, the JOURNAL can continue to publish some of the best articles that the members of the Academy can write.

The Treasurer further wishes to call the attention of the members to the fact that Mr. L. H. Tiffany of the Department of Botany of the Ohio State University, has been appointed subscription manager of the JOURNAL. It is his duty to see that all members who have squared accounts with the Treasurer be supplied with all numbers of the JOURNAL to which they are entitled, without further charges. He is at present attending to all cases of non-delivery of the JOURNAL that have come to his attention. All complaints in the matter of the delivery of the JOURNAL sent to Mr. Tiffany can now be cared for. It is thus to be hoped that the members of the Academy will be promptly served.

Respectfully submitted,

A. E. WALLER, *Tresasurer.*

We have examined the above report and found it to be correct.

Respectfully submitted,

L. B. WALTON,
E. L. FULLMER,
Auditing Committee.

Report of the Executive Committee.

The report of the Executive Committee was received as follows and ordered filed:

March 25, 1921.

To the Ohio Academy of Science:

A meeting of the Executive Committee was held in Columbus, December 18, 1920; all members of the Committee were present.

An invitation was received from Western Reserve University and Case School of Applied Science to hold the Annual Meeting for 1921 in Cleveland. The Executive Committee voted unanimously to accept this invitation, and set the date of the meeting for April 1 and 2. The date was later changed by correspondence to March 25 and 26, in order to bring it within the spring recess of Western Reserve University.

The Secretary reported correspondence with Prof. R. C. Friesner, Chairman of the Program Committee of the Indiana Academy of Science, relative to the possibility of a joint field meeting of the two Academies this spring. The joint meeting is rendered difficult by the fact that the Indiana Academy holds a fall meeting for the presentation of papers and a field meeting in the spring, while the Constitution of the Ohio Academy restricts the Annual Meeting to March or April. A joint meeting in the spring must either debar the Ohio Academy from the opportunity for presentation of papers or eliminate the field meeting from the program of the Indiana Academy. The Executive Committee voted its general approval of a joint meeting at some future date, and instructed the Secretary to continue negotiations with the Indiana Academy. The Committee further instructed the Secretary to give notice to the Academy of a proposed amendment to the Constitution removing the present restriction as to the date of the Annual Meeting, unless such amendment shall prove to be contrary to the Charter of the Academy.

The Executive Committee recommended to the Joint Committee on the Election of Fellows that an opportunity be given this year for the nomination of fellows by the present fellows of the Academy on the lines suggested in the pending Constitutional amendment.

Professor Blake was requested to make an investigation of the desirability of an affiliation of the Academy with the Ohio Association of Technical Societies, as suggested in the Annual Meeting of 1919.

The President, Mr. Alexander, was requested to act as Chairman of the Committee on Legislation during the absence of Professor Osborn.

A second meeting was held in Cleveland on the evening of March 24, at which this report was adopted. The President, Treasurer and Secretary were present at this meeting.

Thirty-six new members have been elected during the year, subject to the ratification of the present meeting.

EDWARD L. RICE, *Secretary,*
For the Committee.

Report of the Publication Committee.

The following report of the Publication Committee was received and ordered filed:

The Annual Report of the Thirtieth Meeting (Proc. Ohio Acad. Sci., Vol. VII, Part 5, pp. 117–158) was published on January 17, 1921. It contains the Constitution and By-Laws in addition to the usual matter. Fifty reprints each of the list of members and of the Constitution were also printed. The present arrangement of printing the Secretary's report in the November issue of the OHIO JOURNAL OF SCIENCE followed soon after by the complete annual report seems satisfactory.

Respectfully submitted,
JOHN H. SCHAFFNER, *Chairman.*

Report of Library Committee.

A brief report for the Library Committee was prepared for the meeting by Mr. Reeder; but, owing to a delay in the mail, this report was not received by the secretary until after the close of the meeting. The following report has since been received for publication.

March 23, 1921.

To the Ohio Academy of Science:

The Library Committee begs leave to submit the following report:

(1) The sale of publications during the year has amounted to $1295.

(2) The Proceedings of the 30th annual meeting of the Academy were published in the OHIO JOURNAL OF SCIENCE for November, 1920. Reprints were received late in February and copies were mailed immediately to all persons on the membership roll and to sixty-eight institutions on the exchange list.

(3) The University Library again calls to the attention of the Academy its willingness to lend to any member, through his institutional library, any publication needed in research work. The library is receiving the exchanges from the Ohio Academy and from the OHIO JOURNAL OF SCIENCE, and together with its own purchases and collections in the scientific fields, there is available a remarkable source of literature for advanced study and research. It is hoped that more use will be made of these sources by the scientific men of Ohio.

Very respectfully,

C. W. REEDER.

Report of the Trustees of the Research Fund.

The following report of the Trustees of the Research Fund was received and ordered filed. The financial portion of the report was referred to the Auditing Committee, whose report is appended.

To the Ohio Academy of Science:

The Trustees of the Research Fund submit the following report for the period from May 12, 1920, (the date on which the last report was made), to March 1, 1921.

During this period only two payments from the fund were made: To L. B. Walton, the balance of the grant made to him in 1917, for the study of fresh water organisms; to Miss Elsie Jordan, for a continuation of the work of relabeling the Harper collection of Naiades, under the direction of W. H. Beecher, to whom the grant was made.

Unexpended balances remain to the credit of A. E. Waller, for the study of Ohio vegetation, and to W. H. Bucher, for aid in the making of a geological map of the disturbed area in Adams County, Ohio.

A grant of $150 was made on January 10, 1921, to W. J. Koster, to aid in a survey of the Orthopteran fauna of Ohio.

Correspondence is in progress which may lead to a renewal of the grant made to Paul B. Sears on June 1, 1819, and a further allotment to W. H. Bucher, for the continuation of work originally undertaken by them.

Below is a tabulated statement of receipts and expenditures during the period covered by this report. In this, it will be noted, is included a one hundred dollar Liberty Bond received from the Treasurer of the Academy to be added to the Research Fund and which is held as a more or less permanent investment along with that purchased in 1918. The accrued interest on both of these bonds is added to the active assets of the funds.

At present the amount available for allotment is $569.96, from which it will appear that the demand for the somewhat restricted financial aid to research which this fund furnishes has not been very great during the past year.

Vouchers for all expenditures are submitted herewith, together with the Cashier's certificate of the balance in the bank on March 1, 1921.

RECEIPTS.

Cash in bank May 1, 1920, as per report of that date	$644.68	
Interest on new Liberty Bond, May 15 and July 28, 1920	6.27	
Interest on Liberty Bonds, Feb. 23, 1921	12.76	
Check from Mr. W. Gluttin, Feb. 23, 1921	250.00	
		$913.71

EXPENDITURES.

Elsie Jordan, June 19, 1920	$22.50	
L. B. Walton, January 7, 1921	20.31	
		42.81

ASSETS.

Cash in bank, March 1, 1921	870.90
Total Assets, Liberty Bonds at par	$1,470.90

LIABILITIES (UNDER GRANTS)

A. E. Waller	$ 75.00	
W. H. Bucher	75.94	
W. J. Koster	150.00	
		$300.94
Excess of Available Assets over Liabilities		$569.96

(Signed) T. C. MENDENHALL, *Chairman.*
HERBERT OSBORN.

We have examined the report and found it to be correct.

L. B. WALTON,
E. L. FULLMER,
Auditing Committee.

March 25, 1921.

Report of Committee on Legislation.

Professor Herbert Osborn, chairman of the Committee on Legislation, submitted the draft of a proposed bill looking to recognition and financial support of the Academy by the State. The bill, as submitted, is modeled after that establishing the State Archaelogical Society. It was written by Mr. Edge, official "bill drafter" for the Assembly, in consultation with President Alexander, who acted as chairman of the Committee during Professor Osborn's absence from Ohio.

After extended discussion, the report was adopted by the Academy, with minor amendments of the bill, and the Committee was continued with instructions to carry on the campaign. President Alexander was added to the Committee, which, as now constituted, consists of the following: Herbert Osborn, chairman; W. H. Alexander, T. C. Mendenhall, M. M. Metcalf, E. L. Rice, L. B. Walton.

The Committee was instructed to draft such revision of the Constitution of the Academy as may be necessary in case the bill is passed by the Assembly, this action to be interpreted as notice of amendment of the Constitution and as enabling the Academy to take final action at the next annual meeting.

The proposed bill, including the amendments voted by the Academy, follows:

A Bill

Relative to State recognition of the Ohio Academy of Science.

Be it Enacted by the General Assembly of the State of Ohio:

Section 1. The Ohio Academy of Science, a corporation not for profit, incorporated under the laws of Ohio, March 12, 1892, shall be under the control of a board of trustees consisting of fifteen members to serve without salary or per diem. Six of the members of the board shall be appointed by the governor with the advice and consent of the Senate, two to serve for two years, two to serve for four years and two to serve for six years, and until their successors are appointed and qualified, and thereafter two members shall be appointed every two years to serve for a term of six years. The remaining nine members of the board shall be elected by the members of the Academy.

Section 2. On and after the passage of this act, the Ohio Academy of Science shall constitute an official source of advice and information on all scientific questions within its field submitted to it by any state department or officer thereof. The services of the Academy shall be available to the state or any of its officers in any matter within its field in which the consideration of scientific facts or policies may be involved, and the officers of the state may call upon the Academy of Science, through its properly elected officers or committees appointed by its officers, for such consultation and advice as may be of service to them in their duties. The members of such committees shall receive no compensation for their services, except that all traveling, clerical and other necessary expenses shall be

paid. No member of the Ohio Academy of Science, while serving on any such committee, shall be eligible for expert service under advice from said committee for which compensation from the state is received.

SECTION 3. One copy of the "Proceedings of the Academy" shall be distributed to each public library and museum, university, college, normal schools, and first grade high school in the state, and one copy of each number of its official organ, "The Ohio Journal of Science," shall be distributed to each university and college in the state. All exchanges received shall be kept available to the citizens of the state through the library of The Ohio State University, or such other channel as may be determined.

SECTION 4. The secretary of the Ohio Academy of Science shall be a person well suited by training and experience to perform his duties and may be paid from state funds.

SECTION 5. The legislature shall make such appropriations from year to year as may be necessary to print the official publications of said Academy and to carry out the other provisions of this act.

Report of Committee on Preservation of Wild Life of State.

In addition to an oral report by the chairman concerning the conservation work already accomplished in Ohio and other states, the Committee presented the following formal recommendations. The recommendations were adopted by the Academy, and the Committee continued under the changed name suggested: Committee on State Parks and Conservation.

The Committee on Preservation of Wild Life of State would recommend:

(1) That the present Committee be continued as a Committee on State Parks and Conservation, to study the various problems involved and to report a matured plan for further action by the Academy.

(2) That all members co-operate in listing suitable tracts for use as state parks, bird reserves, and reservations for the permanent preservation of areas possessing scenic, geologic, or biologic interest.

(3) That the committee proceed to secure co-operation with existing organizations in the preservation of natural conditions in the state forests, game refuges, state controlled tracts, and other areas where such co-operation is possible.

HERBERT OSBORN,
J. ERNEST CARMAN,
FRANCIS H. HERRICK,
C. G. SHATZER,
E. N. TRANSEAU,
MAYNARD M. METCALF,
Committee.

Report of Committee on Election of Fellows.

The following report of the Committee on Election of Fellows was accepted and ordered filed:

March 25, 1921.

To the Ohio Academy of Science:

The method of work of the Committee on the Election of Fellows has been as follows:

(1) Through the preliminary announcement of this meeting, the entire membership of the Academy was given the opportunity to make nominations for fellowship. A single nomination was received.

(2) Copies of the membership list were mailed by the Secretary to the eleven members of the joint committee to be checked as nominating ballots. Nine ballots were returned. Five members received three ballots each, four received two ballots, and thirty-four received one ballot.

(3) A meeting was held in Cleveland on the evening of March 24th, at which seven members of the joint committee were present, two were represented by duly authorized proxies, two were absent without representation.

After careful consideration and discussion, seventeen members received the necessary nine votes and were declared elected to fellowship in the Academy. The newly elected fellows will be personally notified, and the list will appear in the Proceedings.

In addition to the constitutional specification of "productive scientific work" as a condition for fellowship, the committee has been guided by the following principles, which it recommends as a general policy for future action:

(1) Members should not be elected to fellowship in the Academy until one year, at least, after election to membership.

(2) Resident members should not be elected to fellowship who are not showing an active interest in the work of the Academy.

This year's committee, like that of last year, took the ground that its action should be conservative. It is probable that good candidates for fellowship have been passed over; it will be the duty of future committees to correct these omissions.

Respectfully submitted,

EDWARD L. RICE, *Secretary.*,
For the Committee.

The list of members elected to fellowship is as follows:

G. F. ARPS
H. H. M. BOWMAN
E. LUCY BRAUN
HAROLD E. BURTT
DWIGHT M. DELONG
CARL DRAKE
WM. LLOYD EVANS
EMERY R. HAYHURST
WM. E. HENDERSON
J. S. HOUSER
JAMES ERNEST KINDRED
SIDNEY ISAAC KORNHAUSER
FLORENCE MATEER
H. C. OBERHOLSER
PAUL B. SEARS
VICTOR STERKI
B. W. WELLS

Election of Officers.

The following officers and committee members for 1921-'22 were elected by the ballot of the Academy:

President—Professor R. C. OSBURN, Ohio State University, Columbus.

Vice-Presidents:

Zoology—Dr. J. E. KINDRED, Western Reserve University, Cleveland.

Botany—Professor E. N. TRANSEAU, Ohio State University, Columbus.

Geology—Professor J. E. HYDE, Western Reserve University, Cleveland.

Physics—Professor W. G. HORMELL, Ohio Wesleyan University, Delaware.

Medical Sciences—Professor F. C. WAITE, Western Reserve University, Cleveland.

Psychology—Professor RUDOLPH PINTNER, Ohio State University, Columbus.

(Professor Pintner later resigned the Vice-Presidency, owing to removal from the state, and was appointed by the Executive Committee to fill the vacancy.)

Secretary—Professor E. L. RICE, Ohio Wesleyan University, Delaware.

Treasurer—Dr. A. E. WALLER, Ohio State University, Columbus.

Elective Members of Executive Committee—Mr. W. H. ALEXANDER, U. S. Weather Bureau, Columbus; Professor L. B. WALTON, Kenyon College, Gambier.

Member of Publication Committee—Professor L. G. WESTGATE, Ohio Wesleyan University, Delaware.

Trustee of Research Fund—Dr. T. C. MENDENHALL, Ravenna.

Member of Library Committee—Professor W. C. Mills, Ohio State University, Columbus.

Representatives on Editorial Board of Ohio Journal of Science:

Zoology—Professor R. A. BUDINGTON, Oberlin College, Oberlin.

Botany—Professor BRUCE FINK, Miami University, Oxford.

Geology—Professor G. D. HUBBARD, Oberlin College, Oberlin.

Physics—Professor S. J. M. ALLEN, University of Cincinnati, Cincinnati.

Medical Sciences—Professor F. C. WAITE, Western Reserve University, Cleveland.

Psychology—Professor H. A. AIKINS, Western Reserve University, Cleveland.

Election of Members.

The Membership Committee reported eleven names for election to membership; thirty-six additional names, previously approved by the Executive Committee and marked with (*) in the following list, were presented for ratification. All were elected, as follows:

*Ainslee, Geo. G.; Entomology; U. S. Entomological Laboratory, R. D. 9, Knoxville, Tenn.
Altaffer, L. B., Chemistry; 7013 Clinton Ave., Cleveland.
*Bean, Raymond Jackson; Physiology, Embryology; Biological Laboratory, Western Reserve University, Cleveland.
*Chase, Samuel Wood, Zoology; 1353 E. 9th St., Cleveland.
*Chassell, Laura M., Psychology; Dept. of Psychology, Ohio State University, Columbus.
*Clayton, Edward E.; Botany; Botany and Zoology Bldg., Ohio State University, Columbus.
*Devereaux, W. C.; Meteorology; Weather Bureau Office, Cincinnati.
*Dobbins, Raymond A.; Botany, Entomology; Dept. of Botany, Ohio State University, Columbus.
*Dockeray, F. C.; Psychology; Ohio Wesleyan University, Delaware.
*Emery, E. H.; Meteorology; 829 Society for Savings Bldg., Cleveland.
*Friedlander, Mae; Bacteriology, Biology; 343 Carroll St., Akron.
*Goddard, Henry H.; Psychology, Sociology; 1638 Granville St., Columbus.
*Hartley, Edwin A.; Entomology; Dept. of Zoology and Entomology, Ohio State University, Columbus.
*Hayhurst, Emery R.; Medical Sciences; Dept. of Public Health and Sanitation, Ohio State University, Columbus.
Hills, Myra E.; Psychology; 2066 E. 100th St., Cleveland.
*Jones, J. W. L.; Psychology; Heidelberg University, Tiffin.
*Knouff, Ralph A.; Medical Sciences; Ohio State University, Columbus.
*Luckey, Bertha M.; Psychology; Board of Education, Cleveland.
*Manson, Edmund S., Jr.; Astronomy, Physics, Mathematics; Ohio State University, Columbus.
*Marshall, Helen; Psychology; Ohio State University, Columbus.
Martin, John R.; Physics; Dept. of Physics, Case School of Applied Science, Cleveland.
Mather, Kirtley F.; Geology; Denison University, Granville.
Moore, Dwight M.; Botany; Granville.
*Morse, Paul Franklin; Geology; Asst. State Geologist, Jackson, Miss.
*Moxom, Walter J.; Meteorology, Physics, Psychology; U. S. Weather Bureau Office, Dayton.
*Murchison, Carl; Psychology; The Tallawanda, Oxford.

*Myers, Garry C.; Psychology; Cleveland School of Education, Cleveland.
Niehaus, Wm. E.; Zoology, Geology; Berea.
*Olin, Oscar E.; Psychology, Sociology; University of Akron, Akron.
*Patten, Bradley M.; Zoology, especially Embryology; 1353 E. Ninth St., Cleveland.
*Patton, Leroy; Geology; Muskingum College, New Concord.
*Rea, Paul M.; Natural History Sciences, especially Zoology; The Cleveland Museum of Natural History, Cleveland.
Riley, C. L.; Biology, Geology; 1219 Logan Ave., N. W., Canton.
*Roots, Yale K.; Physics; 412 N. Walnut St., Wooster.
Ross, Herbert W.; Chemistry, Geology; West Technical High School, Cleveland.
*Sayre, Jasper D.; Botany; Dept. of Botany, Ohio State University, Columbus.
*Skaggs, Ernest B.; Psychology; 23 S. Union St., Delaware.
Smith, Ella Thea; Botany, Zoology; P. O. Box 7, Salem.
Smith, Ernest Rice; Geology, Paleontology; 130 Woodland Ave., Oberlin.
*Stone, Julius F., General Science, Grandview, Columbus.
*Strausbaugh, P. D.; Botany, Microchemistry as applied to Plant Physiology; Burbank Road, R. F. D. 10, Wooster.
Tippie, William A.; Physics; 2145 W. 100th St., Cleveland.
*Watson, A. C.; Psychology; Marietta College, Marietta.
*Webb, Robert Fulton; Geology; Dept. of Geology, Ohio State University, Columbus.
*Williams, R. D.; Philosophy, Psychology; Dept. of Philosophy, Ohio State University, Columbus.
*Wurdack, Mary E.; Botany; 29 Twelfth Ave., Columbus.
*Young, Herman H.; Psychology, Educational Research; 235 Chapel Place, Youngstown.

Report of Committee on Necrology.

The following report of the Committee on Necrology was adopted by the Academy and ordered filed.

Thomas Piwonka.

September 10, 1854—May 9, 1920.

I first met Thomas Piwonka on the field excursion of the Academy for geology in May, 1919. The failing sight and frailty of age prevented him from participating in full, and he carefully withheld himself from much of the trip that he might not in any way impede the progress of the party. This thought for others was characteristic.

This was less than a year before his death. I saw him but six or eight times in the interval, but these meetings brought us together on the Cleveland shale outcrops of Big Creek which he had often searched for Devonian fish, in his own study and in my laboratory. There are

few men that it is possible to know on so short an acquaintance, yet due to a common interest in fossils. I may, I believe, fairly claim to have attained a certain intimacy with him.

It began when he modestly offered to go with me and show me, if I cared to have him, the localities where Dr. Clark, of Berea, had been most successful in his search for fossil fish. "If I cared!" To me, it is an opportunity forever lost that I was able to visit only one locality with this man who had been the intimate companion of Dr. Clark, the indefatigable collector, and Edward Claypole, the elucidator, of the Cleveland shale fish.

With the same modesty, almost with depreciation lest he might seem to intrude himself, he invited me to look over his small collection of fossils from the Cleveland district. When he learned that Western Reserve University possessed almost nothing from the Cleveland shale, he offered me anything of his from that formation "which might be worth having;" the University gratefully received it all. After his death, Mrs. Piwonka, at his request offered the remainder of the collection to the University, "such portion as might be thought worth having." The whole collection is not large, but contains much material from the Cleveland and Sandusky regions, all carefully marked as to locality, all valuable, particularly that from the Cleveland shale which yields material only on long careful search. Some of the material is unique. In earlier years, he had been equally generous with his findings, and the collections of both the United States Geological Survey and of the Dominion Geological Survey of Canada, have been enriched at his hands; in the days when Dr. Clark combed all Cleveland fish-producing localities twice yearly, an occasional choice specimen was obtain by him from Mr. Piwonka, which must since have lodged either in the British Museum or the American Museum of Natural History.

Before his death, he donated to the Department of Geology of Western Reserve University a generous sum of money to defray expenses of members of the department in making extensive field trips or elaborate collections. The donation was unsolicited, and was made with the firm assertion that he did not do it in any effort to perpetuate his name (indeed, he rather insisted that his name be left out of it); that though fortune had not been lavish with him, yet she had not been unkind, perhaps kinder than to most individuals engaged in University work, and he wished to defray a part of the expense that they are frequently put to in the prosecution of their interests. This sum has already been of service, and will be of yet more service, in the recovery of the last fish and amphibian remains that can possibly be obtained from the famous old Linton Coal-Measures locality of eastern Ohio.

Mr. Piwonka was born in New York City of Bohemian stock. He was valedictorian of his class from Central High School, Cleveland. His interest in natural science was first aroused by S. G. Williams, then a teacher in Central High School (who later became Professor of Education in Cornell University, and whose collection forms the bulk of the paleontological collection of Western Reserve University). After

graduation, Mr. Piwonka acted as secretary to the superintendent of schools for several years, during which time he found time to prepare himself for admission to the bar in 1876. His life-work was law, but in spare moments he was a naturalist with particular interest in geology, botany and microscopy. His passing removes one more (very few are left) of that generation of men interested in the natural history of their locality, with the collector's keen instinct, to which paleontology is profoundly indebted. With them is passing a phase of our culture.

J. E. Hyde, *Committee.*

Report of Committee on Resolutions.

The following resolutions were presented by the Committee on Resolutions and adopted by the Academy:

(1) The Academy wishes to thank the Local Committee, the officers of Western Reserve University and Case School of Applied Science for their efforts in making the Thirty-first Annual Meeting of the Ohio Academy of Science a success.

(2) The Academy wishes to express its appreciation of the continued interest and financial support given to the research work of this Academy by Mr. Emerson McMillin.

(3) The Academy wishes to express to Professor Charles A. Kofoid, of the University of California, its thanks for the special lecture on "Hookworm and Human Efficiency."

(4) The Academy wishes to thank again Professor E. L. Rice for his efficient services as Secretary of this Academy.

C. G. Shatzer.
Raymond C. Osburn.
Walter H. Bucher.

Amendment of Constitution.

Art. V, Section 3. *Election of Fellows.* Amended to read: Fellows shall be elected by joint action of the Executive Committee and the Vice-Presidents, from nominations endorsed by two fellows of the Academy. Such nominations shall be accompanied by documentary evidence of the candidate's scientific achievements upon which the nomination is based. Approval by three-fourths of this joint committee shall be necessary to election.

Amendment of By-Laws.

Chap. III, Section 5. *Nomination of Fellows.* New section, to read: A suitable blank for nomination of fellows shall be supplied by the Secretary and shall be mailed to each member of the Academy at least once each year.

Chap. IV, Section 2. *Nominations.* Amended to read: The Academy shall elect by ballot a Nominating Committee, consisting of one representative from each regularly organized Section of the Academy, who shall nominate a candidate for each office, including elective members of the Executive Committee, the Publication Committee, and the Trusteees of the Research Fund. Additional nominations may be made by any member of the Academy.

Proposed Amendment of Constitution.

The following amended form of Art. VI, Section 1, was proposed by the Executive Committee for action at the next annual meeting: *Annual Meeting.* The date and place of the Annual Meeting shall be fixed by Executive Committee, subject to such instructions as shall be determined by the Academy at the preceding annual meeting, and shall be announced by circular at least thirty days before the meeting. The details of the daily sessions of each meeting shall be arranged by the Program Committee and announced in the official program immediately before the meeting.

The Committee on Legislation was also instructed to make such revision of the Constitution and By-Laws as may be necessitated in case the Legislature shall pass the proposed bill providing for State support of the Academy, this instruction to be interpreted as notice of proposed amendment, enabling definitive action at the next annual meeting.

Certificate of Election to Fellowship.

The Secretary was instructed to prepare a suitable certificate to be presented to each newly elected fellow in the Academy.

Appeal from University of Debreczen.

An appeal from the Director of the Geographical Institute of the Royal University of Debreczen (Hungary), under date of December 7, 1920, for "books, used clothes, and even little sums of money" for the desperately needy students of the department, was read by the Secretary. No action was taken by the Academy beyond thus calling the matter to the attention of the individual members.

Scientific Sessions.

The complete scientific program of the meeting follows:

PRESIDENTIAL ADDRESS.

Thunderstorms; especially those of Ohio.....W. H. ALEXANDER

PUBLIC LECTURES.

Hookworm and human efficiency.....CHARLES A. KOFOID
Scientific work at the Ohio Bureau of Juvenile Research....HENRY H. GODDARD

PAPERS.

1. The new Cleveland Museum of Natural History. (15 min.)....PAUL M. REA
2. The state park situation in Ohio. (15 min.).....J. ERNEST CARMAN
3. Chronological view of men of science. (7 min.).....J. A. CULLER
4. A peculiar case of stature inheritance. (3 min.).....A. B. PLOWMAN
5. A differential sensitivity theory of time and space and its bearing on evolution. (7 min.).....L. B. WALTON
6. The relation of the biologist to public health administration. (15 min.), A. B. PLOWMAN
7. The function of the striae and the origin of bilateral symmetry in the euglenoids. (15 min.) (Lantern).....L. B. WALTON
8. The geographical distribution of the genera of Opalinidae. (20 min.), (Opaque projection).....MAYNARD M. METCALF
9. Hemiptera of the Adirondacks. (10 min.) (Lantern).....HERBERT OSBORN
10. Collecting in southern Florida. (10 min.).....HERBERT OSBORN
11. Some studies in Hessian fly emergence. (10 min.) (Lantern)..T. H. PARKS
12. Notes on the habits and life history of Galeatus peckhami Ashm. (5 min.) (Lantern).....CARL J. DRAKE
13. A new Ambrosia beetle: notes on the work of Xyloterinus politus Say. (6 min.) (Lantern).....CARL J. DRAKE
14. Phylogeny and distribution of the genus Libellula. (20 min.) (Lantern), CLARENCE H. KENNEDY
15. Aids in teaching elementary cytology. (By title).....Z. P. METCALF
16. The cytology of the sea-side earwig Anisolabis. (15 min.)..S. I. KORNHAUSER
17. Copulation in Planaria maculata. (5 min.).....R. A. BUDINGTON
18. On the regulative capacity of the neural tube. (15 min.) (Lantern), H. L. WIEMAN
19. The musculature of the head and throat of the Chimaera ogilvyi. (15 min.) (Lantern).....MAE FREIDLANDER
20. New models of the development of the heart in the chick. (20 min.), BRADLEY M. PATTEN
21. Some features of the morphology of the kidney of Necturus. (20 min.), S. W. CHASE
22. Orientation in the cat. (5 min.).....FRANCIS H. HERRICK
23. Diet of a captive mole. (5 min.).....E. L. MOSELEY
24. Additions to the birds of Ohio. (10 min.).....LYNDA JONES
25. Phagocytoses and clotting in the perivisceral fluid of Arbacia. (10 min.), J. E. KINDRED

26. Further observations as to effect of thyroid substance on plant protoplasm. (5 min.).....R. A. BUDINGTON
27. The origin and development of the prairie in North America. (40 min.), (Lantern).....H. C. SAMPSON
28. The significance of native vegetation in crop production. (35 min.), (Lantern).....A. E. WALLER
29. Energy relations of an acre of corn. (5 min.).....E. N. TRANSEAU
30. Some energy relations of aquatic life and their significance. (10 min.), L. H. TIFFANY
31. Contributions to the genetics and cytology of parthenogenetic Taraxaca. (5 min.).....PAUL B. SEARS
32. Reversal of the sexual state in the Japanese hop. (10 min.)..J. H. SCHAFFNER
33. The occurrence and abundance of certain algae in Lake Erie. (10 min.), MALCOLM E. STICKNEY
34. The census of flowering plants on certain small islands of Lake Erie. (8 min.).....MALCOLM E. STICKNEY
35. Causes and consequences of the irregularities in the glacial border in the Ohio Valley. (30 min. (Lantern).....G. FREDERICK WRIGHT
36. Explorations in Eastern Bolivia. (20 min.).....K. F. MATHER
37. Some sub-surface rock channels filled with glacial material. (15 min.), J. ERNEST CARMAN
38. A fault-zone breccia in the Bass Island series. (10 min.)..J. ERNEST CARMAN
39. A disconformable contact at the base of the Sylvania sandstone. (5 min.) J. ERNEST CARMAN
40. The Ordovician and Silurial seas of American Arctic and Subarctic regions and the relation of their faunas to contemporaneous seas of European areas. (20 min.).....AUG. F. FOERSTE
41. Some coastal geology of southern Florida. (20 min.).....G. F. LAMB
42. An interpretation of some Ohio geology. (12 min.).....G. F. LAMB
43. Richmond Ostracoda of especial interest. (10 min.).....W. H. SHIDELER
44. Additions to our knowledge of the Arnheim. (10 min.)....W. H. SHIDELER
45. A Pliocene brackish water fauna near Alexander, La. (10 min.)..E. R. SMITH
46. A modification of Hobbs's method of teaching interpretation of geologic maps. (10 min.).....E. R. SMITH
47. An embryonic volcano in Adams County, Ohio. (15 min.), WALTER H. BUCHER
48. Local geology of Cleveland from an economic standpoint. (25 min.), (Lantern).....FRANK R. VAN HORN
49. The reopening and the end of the Linton (Ohio) Coal-measures, fossil-amphibian locality. (10 min.).....J. E. HYDE
50. The fauna of the Berea Grit; a recurrent Bedford fauna, and its bearing on the age of the Bedford. (15 min.).....J. E. HYDE
51. Some psychology applied to Americanization. (20 min.)..GARRY C. MYERS
52. Scientific direction of childhood—America's greatest social and political responsibility. (30 min.).....HERMAN H. YOUNG
53. Reliability of survey methods in individual diagnosis. (20 min.), FLORENCE FITZGERALD
54. Limiting factors in human behavior. (5 min.).....A. P. Wise
55. Waste of mental ability in our school system. (10 min.)...HELEN MARSHALL
56. (a) Some studies in progress in the Cleveland School of Education. (b) Some data on learning curves. (30 min.).....GARRY C. MYERS
57. College men in the penitentiary. (20 min.).....CARL MURCHISON

58. A preliminary report on retroactive inhibition (with particular reference to two conditions). (20 min.).....E. B. SKAGGS
59. The measurement of psychological effects of fatigue and low oxygen. (20 min. (Lantern).....C. F. DOCKERAY
60. Discussion of the legal status of psychology in Ohio State.
Discussion led by H. AUSTIN AIKINS

DEMONSTRATIONS.

(a) Chromosomal complexes of Anisolabis.....S. I. KORNHAUSER
(b) Geographic distribution maps for the Opalinidae and their hosts,
MAYNARD M. METCALF
(c) New models of development of the heart in the chick.....BRADLEY M. PATTEN
(d) Chart and data relating to an interesting case of stature inheritance,
A. B. PLOWMAN
(e) Multiple ova in Graafian follicles of cat.....EDWARD L. RICE
(f) Sulphur dioxide injury to vegetation.....A. E. WALLER
(g) Illustrations of euglenoids.....L. B. WALTON

THUNDERSTORMS: ESPECIALLY THOSE OF OHIO.*

WILLIAM H. ALEXANDER
Meteorologist, U. S. Weather Bureau, Columbus, Ohio

I. Thunderstorms in General.

1. Introduction

The typical thunderstorm, that is, the thunderstorm complete in every detail from its beginning to its ending, has ever held a unique place in the world of human thought and speculation as evidenced by its large and conspicuous place in ancient mythology, by its scarcely less conspicuous place in the history and literature of the race, and by the earnest consideration it has received from the brightest minds of the scientific age. Not only so, but its physical characteristics are such as to assure it a place of real and permanent interest in our present and future thinking along meteorological lines.

We are told upon apparently good authority[1]† that more myths have gathered about the thunderstorm and its phenomena than about any other natural phenomenon, except possibly light and darkness. And we are quite prepared to believe it when we recall the ominous stillness of the air, the darkness of the sky, the lurid glare of the clouds, the majestic roar of the thunder, and the indescribable effects of the highly electrified bodies on the nerves of many people. If these storms inspire so much awe in the human mind in a scientific age—in these days of our boasted intellectual emancipation—with what unspeakable awe must the primitive mind have regarded them! No wonder the thunderstorm was looked upon as a mystery that pressed for solution or explanation. These early "explanations" have come down to us as myths, which, like most myths, are of interest to us chiefly because they constitute the first efforts of the human mind to explain natural phenomena. Then, as now, a thing was regarded as *explained* when classified with other things with which we are acquainted.

*Presidential address, delivered at the Cleveland meeting of the Ohio Academy of Science.

†For numbers of reference, consult bibliography at close of paper.

We explain, for example, the origin, the progress and the ending of a thunderstorm when we classify the phenomena presented by it with other more familiar phenomena of vaporization and condensation. But primitive man explained the same thing, to his own satisfaction at least, when he classified it along with the well-known phenomena of human volition by constructing a theory of a great black dragon pierced by the unerring arrows of an heavenly archer. As late as 1600, a German writer would illustrate a thunderstorm destroying a crop of corn by the picture of a dragon devouring the produce of the field with his flaming tongue and iron teeth. But we of today no longer regard the thunderstorm as an object of terror or as an unfathomable mystery, but rather as a natural phenomenon of great economic and scientific interest, one in every way worthy of our best and most serious consideration.

The physics and physical features of the thunderstorm are, we believe, fairly well understood. These have been ably and fully discussed by Professor Humphreys of the U. S. Weather Bureau, whose teaching we follow very closely in this discussion. If the thunderstorm produced *only* lightning and thunder, it would be of only relative importance, but it may bring along a whole series of redoubtable phenomena, thus presenting problems of real practical importance—problems the magnitude and importance of which are not always fully appreciated.

2. Definition

And now, first of all, let us ask and answer, if we can, this question: "What is a thunderstorm?" Ordinarily, for example, we think of a windstorm as a storm characterized by high and perhaps destructive *winds;* of a hailstorm as one characterized by the production of *hail;* of a snowstorm as one that produces *snow;* of a dust storm as one characterized by a great quantity of flying *dust;* and so, quite properly, we think of a thunderstorm as a storm characterized by *thunder* and lightning. This may not, I grant you, serve as a satisfactory *definition*, but it will, perhaps, be a sufficient *answer* for the time being to the question asked.

It is not necessary in this presence, perhaps, to point out that the "snow," the "wind," the "hail," and the "dust," are in no sense the *cause* of the storm to which they give name.

Nor, so far as known, have the lightning and thunder any influence on the formation, progress and termination of the thunder-storm, although they may and often do constitute the most impressive, spectacular, and even tragic features of the storm. For as Prof. Humphreys well says,[2] "No matter how impressive or how terrifying these phenomena may be, they never are anything more than mere incidents to or products of the peculiar storms they accompany. In short, they are never in any sense either storm-originating or storm-controlling factors."

3. Source of the Lightning

Since we cannot have a thunderstorm without thunder, and cannot have thunder without *lightning*, it seems quite essential to a proper understanding of these storms to get a correct, scientific explanation of the source or cause of the lightning. Oh, yes, we are fully aware of the danger just here—namely, how easily and how quickly one may get beyond his depth when talking about the origin of electricity. We must admit, of course, that we know very little if anything for certain at this point, but then we would like to *appear* to know something about this interesting phase of our discussion. We are deeply indebted to Dr. G. C. Simpson[3] of the Indian Meteorological Department for our best information or knowledge on this point. Dr. Simpson, by numerous observations and laboratory experiments found out a great many extremely valuable things concerning the electricity brought down by the raindrop and the snowflake, and at the same time, by means of a number of well-devised experiments, determined the electrical effects of each obvious process that takes place in the thunderstorm. He found out, for example, that no electrification resulted from freezing and thawing, air-friction, etc., but that when he allowed drops of *distilled water* to fall through a vertical blast of air of sufficient strength to produce some spray,

(1) That breaking of drops of water is accompanied by the production of both positive and negative ions.

(2) That three times as many negative ions as positive ions are released.

"Now," as pointed out by Professor Humphreys[2], "a strong upward current of air is one of the most conspicuous

features of the thunderstorm. It is always evident in the turbulent cauliflower heads of the cumulus cloud, the parent, presumably, of all thunderstorm. Besides, its inference is compelled by the occurrence of hail, a frequent thunderstorm phenomenon, whose formation requires the carrying of raindrops and the growing hailstones repeatedly to cold and therefore high altitudes. And from the existence of hail it is further inferred that an updraft of at least eight meters per second must often occur within the body of the storm, since, as experiment shows, it requires approximately this velocity to support the larger drops, and even a greater velocity to support the average hailstone.

"Experiment also shows that rain can not fall through air of ordinary density whose upward velocity is greater than about eight meters per second, or itself fall with greater velocity through still air; that in such a current, or with such a velocity, drops large enough, if kept in tact, to force their way down, or, through the action of gravity, to attain a greater velocity than eight meters per second with reference to the air, whether still or in motion, are so blown to pieces that the increased ratio of supporting area to total mass causes the resulting spray to be carried aloft or left behind, together with, of course, all original smaller drops. Clearly, then, the updrafts within a cumulus cloud frequently must break up at about the same level innumerable drops which, through coalescence, have grown beyond the critical size, and thereby according to Simpson's experiments, produce electrical separation within the cloud itself. Obviously, under the turmoil of a thunderstorm, its choppy surges and pulses, such drops may be forced through the cycle of union (facilitated by any charges they may carry) and division, of coalescence and disruption, from one to many times, with the formation on each at every disruption, again *according to experiment*, of a correspondingly increased electrical charge. The turmoil compels mechanical contact between the drops, whereupon the charges break down the surface tension and insure coalescence. Hence, once started, the electricity of a thunderstorm rapidly grows to a considerable maximum.

"After a time the larger drops reach, here and there, places below which the up-draft is small—the air can not be rushing up everywhere—and then fall as positively charged rain,

because of the processes just explained. The negative electrons in the meantime are carried up into the higher portions of the cumulus, where they unite with the cloud particles and thereby facilitate their coalescence into negatively charged drops. Hence, the heavy rain of a thunderstorm should be positively charged, as it almost always is, and the gentler portions negatively charged which very frequently is the case.

"Such in brief, is Dr. Simpson's theory of the origin of the electricity in thunderstorms, a theory that fully accounts for the facts of observation and in turn is itself abundantly supported by laboratory tests and simulative experiments.

"If this theory is correct, and it seems well founded, it must follow that the *one essential* to the formation of the giant cumulus cloud, namely, *the rapid uprush of moist air*, is also the one essential to the generation of the electricity of thunderstorms. Hence the reason why lightning seldom if ever occurs except in connection with a cumulus cloud is understandable and obvious. It is simply because the only process that can produce the one is also the process that is necessary and sufficient for the production of the other."

4. Turbulence of the Cumulus Cloud.

That the large cumulus clouds, especially those that produce thunderstorms, are exceedingly turbulent within with violent vertical motion, as demanded by the theory just outlined, is evident to even the casual observer. Furthermore the testimony of those balloonists who have had the trying ordeal of passing through the heart of a thunderstorm confirms the facts of observation. Since these are the only clouds, apparently, characterized by this high degree of turbulence, it may be well to pause a moment and ask why these motions—motions which, in the magnitude of their vertical components and degree of turmoil, are never exhibited by clouds of any other kind nor are they met with elsewhere by either manned, sounding or pilot balloons. Without going into very great detail, it may be pointed out, as has been done by von Bezold[4], that the heat liberated by the sudden condensation from a state of supersaturation, and also from the sudden congelation of undercooled cloud particles, would cause an equally sudden expansion of the atmosphere, resulting in turbulent motions analogous to those observed in the large cumulus clouds.

This, however, is not sufficient to account for all the observed facts, since it is not clear just how either the condensation or the congelation could suddenly take place throughout a cloud volume great enough to produce the observed effects. We must, therefore, look for some other explanation, and this we shall probably find, *in the difference between the actual temperature gradient of the surrounding atmosphere and the adiabatic temperature gradient of the saturated air within the cloud itself;* or, in other words, the cause of the violent up-rush and turbulent condition within large cumulus clouds is, presumably, the difference between the temperature of the inner or warmer portions of the cloud itself and that of the surrounding atmosphere at the same level.

5. Causes of Convectional Instability.

As we have just tried to show the *sine qui non* of the thunderstorm is the *rapid* vertical convection of *moist air;* the up-rush must be *rapid* and the air must be *moist;* one without the other is not sufficient. We may have, for example, a *very* rapid convection over a desert region but there being no moisture there will be no cloud-formation and therefore no thunderstorm. On the other hand we may have air ever so humid but if the movement upward is too gentle not even a cloud may result, but if a cloud, certainly no thunderstorm. It is obvious, therefore, that we must have both "rapid convection" and "moist air."

This leads us to a consideration of the conditions under which the vertical temperature gradients necessary to this convection can be established. These conditions are, according to Prof. Humphreys, three in number, namely:

(1) A strong surface heating, expecially in regions of light winds.

(2) The over-running of one layer of air by another at a temperature sufficiently lower to induce convection.

(3) The under-running and consequent uplift of a saturated layer of air by a denser layer.

Of these three conditions, the first mentioned—"strong heating surfaces"—is, for obvious reasons, of most frequent occurrence over the land surfaces of the earth; number two is also of frequent occurrence on land and is, perhaps, well nigh the

sole cause of thunderstorms on the ocean. Number three is by far less frequently the cause of thunderstorms than the other two, for while the actual *under-running* is of rather frequent occurrence, it seems probable that only occasionally is the uplift of sufficient magnitude to cause a thunderstorm.

6. Periodic Recurrence of Thunderstorms.

Keeping in mind the conditions or factors absolutely essential to the formation of a thunderstorm, we are well prepared to consider, perhaps in a measure to anticipate, the periodic recurrence and distribution of thunderstorms, for while it is possible, of course, for a thunderstorm to occur on any day at any hour, yet the fact is, and for obvious reasons, the day has its period of maximum thunderstorm activity, the year its maximum period, and there is some evidence of irregular cyclic periods of maximum activity, each maximum depending upon the simple facts that the more humid the air and the more rapid the local vertical convections the more frequent and also the more intense the thunderstorms.

Taking the *day* as our unit, we find the period of maximum thunderstorm activity is not the same over the land as over the ocean. Vertical convection of the atmosphere over the land is most pronounced, of course, when the surfaces are most heated, namely, in the afternoons; hence the inland or continental thunderstorm occurs most frequently, in most places, between 2 and 4 P. M. Over the ocean, however, the temperature gradients that are most favorable for rapid vertical convection are most frequent during the early morning hours, and therefore thunderstorms usually occur on the ocean between midnight and 4 A. M. If we take the *year* as our unit, we find, for reasons that will readily occur to all, that thunderstorms are most frequent, over the land, when the surface heating is at a maximum, in middle latitudes in June and in the higher latitudes in July or August. Over the ocean, however, the thunderstorm is most frequent in the winter months.

Furthermore, since the thunderstorm is vitally associated with rainfall and high temperature, it must follow that a *cycle* of warm, wet years would give a maximum of thunderstorms and a cycle of cold, dry years a minimum.

We have the key to the *geographical* distribution of thunderstorms in the conditions essential to their production, and

while it is safe to say that the thunderstorm, in one form or another, does occur at some time or other in all parts of the earth, yet from what we know of the meteorological conditions ordinarily prevailing over the various portions of the earth, we are very sure that it is very rare over large areas and may never occur in some regions. In the United States[5], for example, we find two centers of maximum thunderstorm activity, one over Tampa, Florida, and the other over Santa Fe, New Mexico. In the ten-year period, 1904-1913, 944 thunderstorms were recorded at Tampa and 710 at Santa Fe. Tampa is near sea-level and Santa Fe is about 7,000 feet above the sea.

7. Classification of Thunderstorms.

One is impressed with the very great variety and many variations met with in the study of these storms. This is true whether one is considering the attendant circumstances, the varying degree of intensity exhibited by them, the frequency of occurrence, the resulting effects, the distribution through the day, the year, or over the earth's surface, or whether one is considering the factors operating to produce and maintain these storms. Variety everywhere!

At one time, and not so long ago, it was thought that all thunderstorms were local phenomena and were therefore not subject to any general law. In an important sense the thunderstorm is a local phenomenon but the forces operating to produce many of them are far from local. It is now known that a majority of these storms travel in a definite direction and are therefore moving under a general law. In general, with respect to the producing causes or conditions out of which they grow, thunderstorms may be divided into (1) local or "heat" thunderstorms, and (2) the cyclonic thunderstorms, or "thundersqualls." Or, if we wish to be a little more exact or "scientific," we may follow Professor Humphreys and make five classes, namely, (1) the "heat" or local, (2) the cyclonic, (3) the tornadic, (4) the anti-cyclonic, and (5) the "border," thunderstorm. The significance of this classification will be pointed out later in connection with the illustrated portion of this lecture but it seems appropriate at this time to refer to Durand-Greville's famous theory of "the squall zone" in connection with cyclonic thunderstorms. He holds that "cyclonic thunderstorms"—and that means all except the "local" or

"heat" thunderstorm—are but an accessory result of a body of extremely complex phenomena—an organism someone has called it[6]—the *squall*, which is subject to fixed laws and forms an integral part of certain lows. This so-called "squall zone" in which, according to Durand-Greville[7], nearly all "cyclonic" thunderstorms, or as he calls them, "thundersqualls," occur, starts some where near the center of the barometric depression or "low" and usually extends out to its boundary, thus having a length of a thousand miles or more, while its width may vary from 10 to 60 miles or more. This zone moves, advances or recedes, with the "low" of which it is a part, as a rule remaining parallel with itself. Should the "low" remain stationary, the squall zone may, and usually does, swing round the center. The passage of the "squall zone" over any given place, shown by the familiar "squall hook" of the barograph trace, is attended by the concomitant production of certain phenomena that occur only within the limits of the zone. They begin at the moment the "squall front" of the squall zone reaches the place of observation, they rapidly attain their maximum intensity, and then gradually weaken and finally die out as the rear of the zone passes and normal conditions become established. These accompanying phenomena may be more or less numerous, thus giving rise to a variety of "squalls," each characterized by its appropriate phenomena. These squalls have been classified by Durand-Greville as follows, viz.:

DURAND-GREVILLE'S CLASSIFICATION OF SQUALLS[8]

1. Sudden increase in wind velocity	White squall			
2. Sudden change in wind direction				
3. Sudden rise in pressure				
4. Sudden fall in pressure		Wind squall		
5. Sudden rise in relative humidity			Rain, hail, or snow squall	Thunder squall
6. Rapid increase in cloudiness				
7. Downpours of rain, hail, snow				
8. Lightning and thunder				

The basis of this classification is, as you see, increasing complexity. Note also that the phenomena observed during the passage of a squall are actually the results of two causes, one of these, the "squall wind," is purely *dynamic*, pre-existant, and may be of distant origin; the other is the local condition of the atmosphere and is *static*.

8. The Mechanism of the Thunderstorm.

Thus far we have considered the thunderstorm in a more or less general way—its definition, its causes, its recurrence, its distribution, its relation to areas of high and low pressure, etc. Let us now consider *a* typical thunderstorm in actual progress and note its mechanism and some of its more important phenomena. Just here the slide would be very helpful but we shall content ourselves just now with the bare mention of some of the things that one may look for in the well-defined thunderstorm. Among these may be mentioned the winds, the squall cloud, the pressure, the temperature, the humidity, the rain, the hail, the so-called "rain-gush," the rate of advance of the storm, the lightning, and the thunder.

First, the thunderstorm winds must be carefully considered if one is to understand fully the mechanism of the thunderstorm itself. As every one knows, as a thunderstorm approaches a given place the wind at that place is generally light and from a direction that carries it across the path of the approaching storm, that just before the rain begins the wind begins to die down, almost to a calm, and to change its direction. When this change is complete it blows for a few moments, rather gently, directly toward the nearest portion of the storm front, and finally as the rain is almost at hand, there is a sudden change of direction and the wind now comes, often in violent gusts, directly away from the storm and in the direction the storm is moving, a direction quite different from the original direction of the wind. As a rule these strong gusts of wind last through the early part of the storm only and then follow gentle winds again, at first following the storm but after an hour or so they blow from the same general direction as the original surface winds. Now, as we have tried to show, the thunderstorm is the child of a cumulus cloud and the cumulus cloud is the child of a vertical convection which results from a more or less super-adiabatic temperature gradient. This gradient

may be established in one of three ways, as above pointed out. Now, inasmuch as the passage of a cumulus cloud overhead, however large, so long as rain does not fall from it, does not materially disturb the surface winds, in other words, does not bring on any of the familiar gusts and other thunderstorm phenomena, we must infer that in some way the rain is an important factor both in starting and maintaining the winds we have just noted. On the other hand we cannot assume that the rain is the whole cause of these winds for they do not accompany other and ordinary showers, however heavy the rainfall.

The "rain-gush" or heavy downpour after a heavy clap of thunder has often been misunderstood and has been made to serve as a proof of the claims of the so-called "rain-makers." The fact is the rain is the cause of the thunder or lightning, and not the thunder the cause of the heavy rain.

Then there is the *lightning* in its various forms, the "streak" lightning, the so-called "rocker" lightning, the "ball" lightning, the "sheet" lightning, the "beaded" (?) lightning, the "return" lightning, and some people say the "dark" lightning, and so on. To discuss all these would carry us far beyond our limit. Then there is the question of the temperature along the path of a lightning discharge, how does the lightning render the atmosphere through which it passes luminous, etc. Perhaps no one knows the answer to these questions but it is very certain that the temperature along the path of the lightning discharge is very high from the fact that it sets fire to many objects, such as buildings, that fall within its path. Just how the lightning discharge renders its path through the atmosphere luminous is not definitely known. Of course it does make the air along its path very hot but no one so far as I know has ever succeeded by any ordinary means in rendering oxygen or nitrogen luminous by heating. It must be therefore, that the luminosity is due to something besides high temperature, probably, according to Prof. Humphreys, to "internal atomic disturbances induced by the swiftly moving electrons of the discharge." The spectrum reveals to us the interesting fact that lightning flashes are of two colors, white and pink or rose. The rose-colored flashes, when examined in the spectroscope, show several lines due to hydrogen, which of course are due to the decomposition of some of the water along the lightning path. The duration of

the lightning discharge is exceedingly variable, ranging from 0.0002 second for a single flash to, in rare cases, even a full second or more for a multiple flash consisting of a primary and a series of subsequent flashes. The lightning discharge is direct, not alternating, as shown by the fact that the lightning may operate telegraph instruments, may reverse the polarity of dynamos, both of which requires a direct current.

The length of the lightning streak also varies greatly. When the discharge is from cloud to earth the length is seldom more than 2 or 3 kilometers, but when from cloud to cloud may be 10 to 20 kilometers (6 to 12 miles). The path of the lightning discharge may extend from the cloud to earth, from one portion to another of the same cloud, or from one cloud to another cloud. Obviously the second case is of the most frequent occurrence, that is, from the upper to the lower portion of the same cloud; from cloud to earth is next in point of frequency, and from cloud to cloud, relatively rare. Sometimes the discharge from cloud to earth may include in its strange and tortuous path objects that have not sufficient conductivity to carry it and as a result of the sudden and excessive heating many very freakish things may be done, such as shingles blown off, chimneys shattered, trees stripped of their bark or splintered, wires fused, even holes melted through metal, etc. Then there are certain chemical reactions resulting from these electrical discharges that play an important part in the economy of nature. For instance the health-giving ozone of the atmosphere is greatly increased by the passage of a thunderstorm, and even the fertility of the soil may be increased by the production of considerable quantities of ammonia and soluble salts.

Perhaps, a word or two should be said regarding the *danger* to life incident to the passage of a thunderstorm. That there is danger, even great danger at times, is abundantly shown from the tragic statistics of deaths each year from this cause. While it is not possible, perhaps, to remove this danger, it is possible to reduce it, chiefly by avoiding the points of greatest danger. In general, it is safer inside than outside of a house, especially if the house has a well-grounded rod or metal roof; it is also safer in the valley than on a hill or elevated portion of land, this because the chance for a cloud-to-earth discharge varies inversely as the distance between them; it is also very unsafe to take refuge under a tree and the taller the tree the

greater the danger. No tree is immune but those trees having an extensive root system or a deep tap-root are most apt to be struck because they are the best grounded and therefore offer the least electrical resistance. Then again if one is caught out of doors and is exposed to a violent thunderstorm it is best so far as danger from lightning is concerned, to let one's clothes get soaking wet, because wet clothes are much better conductors and dry clothes much poorer conductors, than the human body. It might even be advisable to lie flat on the wet ground, undignified as this may be. For any given locality, the lower the cloud the greater the danger; hence, when the humidity is high it is favorable for a dangerous storm, since the cloud will form at a low level and the rain is apt to be very abundant. For the same reason a winter storm is likely to be more dangerous than a summer storm of equal intensity.

And now how do we account for the *thunder*—that particular feature that gives name to our storm? It has taken quite a while to answer this question satisfactorily. Many very silly theories still persist. The electrical discharge, the "lightning," furnishes the key to the explanation. The sudden and intense heating of the air along the path of the discharge causes it to expand suddenly and violently, sending out from every part of its path a steep compression wave, which, as we understand it, is the real cause of the thunder. The "rumbling" that sometimes follows is due, chiefly perhaps, to the inequality in the distances from the observer to the various portions of the lightning's path, to the crookedness of the path, to a succession of discharges, and to some extent to reflection under favorable conditions. The distance to which thunder may be heard varies from 7 to 15 miles.

9. Forecasting the Thunderstorm.

The forecasting of conditions favorable for the formation of thunderstorms one or two days in advance is comparatively easy but to say, even a few hours in advance, that a thunderstorm will occur at a given place, at or about a given time, is, to say the least, a hazardous venture. It is only after the storm has actually begun and its direction and rate of movement have been determined, can one speak with even a small degree of assurance. As every one knows, a storm may occur, in fact several of them, in sight of the observer and yet not at

the place of observation. Then besides the thunderstorm is of a very limited duration; it may, at the very most, last twenty-four hours, but as a rule a very few hours will exhaust it. It is only when this type of storm assumes the character of a tornado that knowledge of its approach becomes really important.

10. The Thunderstorm and Excessive Precipitation.

Another thing that gives to the thunderstorm economic importance is the fact that from 66 to 100 per cent of all instances of excessive precipitation in the United States occur as the result of or in connection with thunderstorms[9]. Some places, like Bismark, Denver and Sante Fe, excessive precipitation never occurs except in connection with thunderstorms. Furthermore, the records will show that practically all cases of remarkable downpours of rain or hail occur in connection with these storms.

II. Thunderstorms in Ohio.

1. Introduction.

Needless to say, the thunderstorms of Ohio do not differ in any essential respect from those we have been discussing. Our chief and perhaps only excuse for referring to them at this time and in this manner is to make an occasion to call the attention of the Academy to a piece of work accomplished in Ohio that, so far as we know, is the only one of its kind in this or any other country, namely an intensive study of thunderstorms over a limited region through a period of one year. The purposes were to determine as far as practicable the origin, the distribution, the number, the frequency, the extent of territory covered, the attending phenomena, etc., of these storms, and if possible, trace the history of each individual thunderstorm that entered or originated in the state of Ohio, during the year 1917.

2. The Plan.

Our plan was to secure at least one observer in each township in the State but as the work was to be purely gratuitous we were not able to interest one person in each of the 1357 townships. Our total enlistment was about 730 volunteer

observers, about 130 co-operative observers and the six regular Weather Bureau stations in the State. We also received some assistance from the telephone and telegraph companies in the State and even dealers in lightning rods.

3. Forms and Instruction.

Each observer was then supplied with full instructions and a suitable card on which to make his report of each storm. This form called for the exact date and time of the storm, the exact location of the observer, time first, loudest and last thunder was heard, direction the storm moved, time rain began and ended, time hail began and ended, direction of wind before and after the storm, etc. The weakness of the plan was, of course, in the fact that it was dependent upon voluntary service and as was to have been expected, some observers failed us at the critical moment, so that we were not always sure we had the complete history of each storm. However, we assembled quite a mass of thunderstorm data and these have been charted and otherwise prepared for publication.

3. A Resume.

Among the many interesting facts brought out in the special study of thunderstorms in Ohio during the year 1917, may be mentioned, briefly, the following:

(a) Thunderstorms in Ohio are incident to the *passage* of those cyclonic areas (see M. W. R., Supplement No. 1) that move directly over or just north of the State, and to the *approach* of those that move just south of the State. The first group includes the Alberta, the North Pacific, the Rocky Mountain and probably the Central and Colorado types; the second group includes the South Pacific and the Texas types, especially those that follow a northeasterly course.

The passage of the Alberta type, especially in the late winter or early spring months, will cause thunderstorms in Ohio when the wind-shift line, or "squall line," is pronounced, and extends in a north-south, or a northeast-southwest direction. These thunderstorms will set in slightly in advance of this line and will continue until it has passed. See weather map of January 31, 1917, 7 A. M. The passage of the North Pacific, the Northern Rocky Mountain, the Central, and the Colorado

types, will cause thunderstorms in Ohio only when an area of high pressure prevails over the eastern Lake Region or New England. See weather map of April 17, 1917, 7 A. M. As these types are usually followed by a high pressure area from the northwest of more or less intensity and therefore move with considerable rapidity, the thunderstorms incident thereto are apt to be of short duration and are seldom of a violent character.

But to the approach of the South Pacific and Texas types is to be attributed by far the greater portion of the thunderstorms in Ohio. These types prevail from early May into late October. As a rule thunderstorms will set in over the western part of the State when the center of the "low" reaches Missouri or southern Illinois and will probably become general over the State. These cyclonic types often bring thunderstorms of a very violent nature. When the "low" passes over the northwestern corner of the State, thus forcing the isotherms far northward of their normal position, and is followed by a "high" of moderate intensity, hailstorms are likely to occur with the shift of the wind—passage of the squall line—and subsequent increase in pressure. See weather maps of March 10 and 11, 1917. The position of the Atlantic high does not seem to have any material effect on the rain-producing characteristics of these "lows." When the path of these cyclonic types suddenly curves to the north and passes into the Lake Region from northern Indiana or Illinois, thunderstorms are likely to occur in Ohio both on the approach and the passage of these areas. Normally, however, their passage just over or just south of the State is followed by brisk westerly winds, clearing weather and falling temperature.

The East Gulf and South Atlantic types gave rise to no thunderstorms in Ohio during the year 1917.

(b) The data seem to show certain centers of maximum activity and storm-frequency. The southwestern part of the State is certainly the most favorable portion for the development of the tornado as all tornadoes of consequence in the history of the Bureau have occurred in that section.

(c) Thunderstorms were reported on 169 days, midnight to midnight. Of these 169 days, thunderstorms occurred in the forenoon only on 22 days, on the afternoon only on 80 days, on

both forenoon and afternoon on 63 days, on 9 days the storm began in the forenoon and ended in the afternoon, and on 2 occasions the storm began on the afternoon or evening of one day and ended in the early morning of the following day. Note that the afternoon thunderstorm is about four times as frequent as the forenoon, that the number of days with thunderstorms both morning and afternoon is quite large, that the number of days on which the storm begins in the forenoon and continues into the afternoon is quite small and the number beginning in the afternoon or evening and continuing beyond midnight is smaller still.

The reports further show that at leats 31 persons were killed during the year by lightning, 70 others more or less injured; in addition, a large number of animals were killed and much property destroyed. We have no reliable figures as to how many times the lightning actually struck but we learn from the report of the State Fire Marshal that 215 fires were started during the year as the result of a lightning stroke, destroying property valued at about $370,000. The 215 objects damaged or destroyed were classified as follows: 137 barns, 53 dwellings, 4 churches, 4 sheds, 4 warehouses, 2 haystacks, 2 oil tanks, 1 dry cleaning establishment, 1 hotel, 1 livery stable, 1 school house, 1 straw stack, 1 manufacturing establishment and 2 mercantile buildings. The Fire Marshal's office takes no note of lightning strokes that do not start a fire or cause the loss of human life. These fires were distributed through the months as follows, viz.: February, 5; March, 6; April, 5; May, 33; June, 27; July, 45; August, 66; September, 17; October, 11; January, November and December, *none.*

Another item of considerable interest, perhaps, is that about 95 per cent of the objects struck were wet at the time and rain was falling, leaving only about 5 per cent that were dry and struck when no rain was falling. In one case, the burning of a barn near Conneaut, Ashtabula County, March 26th, the report seems to indicate that snow was falling at the time of the stroke that caused the fire.

Another thing: The days on which thunderstorms are general over the State are relatively few. Of the 169 thunderstorm days in 1917, on 7 days only were thunderstorms general; on 11 days they covered about three-fourths of the State; on

23 days about one-half; on 17 days, nearly half the State; on the rest, they were local and limited.

As intimated above, the publication of this report (Thunderstorms in Ohio in 1917) has been and is being delayed on account of lack of the necessary funds.

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